EFFECTIVENESS OF RESIDENTIAL IRRIGATION SYSTEM EVALUATIONS IN REDUCING WATER USE IN COLLEGE STATION, TEXAS

A Thesis

by

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ABSTRACT

Municipal water use is the fastest growing sector of water use in Texas, representing over three million acre-feet of water demand in 2060 according to the 2012 State Water Plan. Landscapes often receive more water than needed for optimum plant health, due to overwatering from inefficiencies in irrigation system design, poor maintenance and operation practices, excessive run times, and lack of understanding of the irrigation controller. Landscape irrigation evaluations are a water conservation practice intended to point out sources of water waste and provide specific recommendations for improving water use efficiency.

This paper presents results of landscape irrigation evaluations conducted in College Station, Texas, between 2010 and 2013. Objectives of this study were to determine change in seasonal irrigation use as a result of receiving an irrigation checkup; determine conformity to a suggested seasonal irrigation budget; and measure changes in amount of excess irrigation over time. Water use was studied for 173 properties in College Station that received an irrigation checkup and exceeded their irrigation budget or had inefficiencies noted during the irrigation checkup, to determine changes in seasonal water use over time and reductions in amount of excess irrigation. Total reduction in seasonal irrigation use was 11.7 million gallons over the four year period of 2011 – 2014, and excess irrigation was reduced by 2 million gallons.

DEDICATION

For my Pappap, who always told me, “You get yourself a good education.”

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NOMENCLATURE

B/CS	Bryan/College Station
ET_0	Reference Evapotranspiration
BVGCD	Brazos Valley Groundwater Conservation District
Kc	Crop coefficient
Kgal	Thousands of gallons
RWPG	Regional Water Planning Group
TWDB	Texas Water Development Board

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1. INTRODUCTION

Many Texas municipalities have reached a crossroad in water management. As water demand rises and new supplies are limited, water planners and managers have identified conservation as a management strategy to extend existing supplies. According to the 2002, 2007 and 2012 Texas Water Plans, municipal water use represents the fastest growing sector among all water user categories in the state (TWDB Texas Water Development Board 2002; 2007; 2012). Projections in the 2007 and 2012 Plans indicate that municipal water conservation strategies can yield more than 600,000 acre-feet of supply for municipal needs. In addition to the conservation imperative in state water plans, the Texas legislature has established funding and regulatory rules requiring water utilities to prepare and submit to state agencies water conservation plans (Title 30 Texas Administrative Code chapter 288 ; Title 31 Texas Administrative Code chapter 363). The content of these plans must include five and 10 year targets with specified and quantified water savings, an implementation schedule and anticipated methods and measures used to achieve the savings.

Conservation and efficiency are often used interchangeably but the literature makes some distinctions between the terms in order to distinguish practices and techniques. Some suggest that conservation implies an overall reduction in the volume of water used over time (Baumann et al. 1984), while others propose (Chestnutt et al. 2008) that efficiency refers to practices that maximize uses per volumetric unit of water supplied.

Although water conservation definitional literature draws distinctions between efficiency, demand management and reduced use, in practice these two terms get blurred or incorporated into a more inclusive definition. Indeed, Texas water plans and conservation legislation characterize water conservation as any techniques and practices that increase efficiency, reduce demands on existing supplies or result in an overall reduction in use (TWDB Texas Water Development Board 2007; 2012). The Texas intent is to use measures in all three categories as a means to conserve water.

Numerous studies have examined residential water use patterns regarding indoor and outdoor water use (Deoreo and Mayer 2012; Litke and Kauffman 1993; Vickers 2001). Generally, indoor water use declines have uniformly occurred throughout the country due to appliance improvements. Patterns of outdoor water use are more varied and are affected by biological, economic, meteorological, soils, slope and irrigation system design and operation factors. However outdoor water use has been increasing but with most of the increases in the more arid regions of the country (Deoreo and Mayer 2012). Outdoor water use as a percentage of total residential use has also increased in Texas (Hermitte and Mace 2012). In their study, about 31 percent of average city water use state-wide was attributed to outdoor water use. There was substantial variation between cities, from a low of 13 percent in one community to a high of 64 percent in another. Given this variability, there are substantial opportunities for outdoor water conservation programs.

One of the primary sources of waste associated with outdoor water use is the irrigation system (TWDB Texas Water Development Board 2013; Vickers 2001). Inefficient irrigation system design, poor maintenance and operation all contribute to overwatering and waste. Landscape irrigation evaluations, often termed water audits or water checks are widely used to promote efficient use and reduce waste (Baum et al. 2005; Olmstead and Stavins 2009; Thomas et al. 2009). These audits are recognized as a best management practice to reduce waste due to overwatering or system defects (TWDB Texas Water Development Board 2013). It is common for landscapes to receive more water than they actually need for optimum health. Water is wasted in irrigation due to inefficiencies in design, maintenance issues such as leaks or misaligned spray heads or that have an incorrect spray pattern for their location, and excessive irrigation zone run times, or the customer may not understand how to program their irrigation controller (Bargar et al. 2004; Endter-Wada et al. 2008; Vickers 2001). These are all problems that can be easily corrected with some instruction, such as that provided through an irrigation evaluation.

Landscape irrigation evaluations have been shown to produce savings of up to 100 gallons per day, or between 5% and 30% post-intervention (GDS & Associates 2002; Gregg et al. 2007; Nelson 1992; Thomas et al. 2009). The California Urban Water Conservation Council notes that an irrigation survey following its guidelines should result in savings of 15% - 20% (CUWCC. California Urban Water Conservation Council 2005; 2014).

In order to produce the most savings, landscape irrigation evaluations should be targeted to customers using the most water, for example the top 5% or 10% of residential customers, or large-landscape commercial customers (TWDB Texas Water Development Board 2013). The San Antonio Water System (SAWS) contacted the top 1% of its single-family residential customers and offered them the option of a water conservation survey, a self-directed water audit, or a water conservation site visit conducted by a trained technician (Rice 2009). Water consumption was tracked for six months following the experimental intervention and SAWS found that customers receiving an on-site visit reduced water on average 9% (Rice 2009).

There are two levels of landscape irrigation evaluations. At the highest level is the audit. The audit includes several steps to evaluate the relationship between soil texture, plant health, and watering patterns, which can be grouped into the areas of site inspection, performance testing, and irrigation scheduling. The site inspection records any deficiencies in the irrigation system and documents site conditions such as soil type and sun exposure. Core samples may be taken to determine soil texture. Performance testing evaluates whether the irrigation system is operating according to manufacturer and design specifications. Application rates and efficiency of sprinkler are documented by collecting data on irrigation zone run times, observing sprinkler patterns, and measuring water applied through a catch-can test (Glenn et al. 2015; Taylor et al. 1999; Thomas et al. 2009). Components of an irrigation system are designed to operate at specific water pressures and distances, and changes in these conditions can cause the system to apply more (or in some cases less) water than plants need. Irrigation scheduling combines findings of the site inspection and performance testing with information about plant water requirements into a watering program designed to meet landscape water needs.

Landscape irrigation evaluations, or water check-ups, are scaled-down versions of a complete audit. They are intended to point out sources of water waste and provide specific recommendations for improving water use efficiency. These landscape irrigation checkups do not include distribution uniformity or soil moisture measurements as described in other literature about irrigation evaluations (Glenn et al. 2015; GreenCO and Wright Water Engineers Inc. 2008; Taylor et al. 1999; Thomas et al. 2009). At the irrigation check-up, the customer is shown how to read their water meter and check the leak indicator on the meter to observe any leaks. Irrigation controller settings are reviewed with the customer, and instruction is given on how to operate the system manually, and use features such as seasonal adjustment, rain delay, and rain sensor. A detailed inspection is then conducted of each irrigation zone, with instruction given on proper placement, maintenance, and operation of sprinkler heads. Throughout the checkup, the customer is shown how to identify parts of the sprinkler system that are operating inefficiently.

Following the checkup, the customer receives a written report documenting the findings including a recommended irrigation schedule noting suggested days to water and run times per station based on plant type, sun exposure, and sprinkler head type. A list of licensed irrigators to contact for any problems that require extensive follow-up is also provided. Any deficiencies, leaks, or other inefficiencies such as mixed head types are noted on the inspection form.

This thesis reports on research conducted in conjunction with College Station sponsored water check-ups offered to homeowners. The water savings efficacy of check-ups was compared over 2 and 3 years. Although research is limited, it is believed that savings from landscape irrigation evaluations can last up to three years, after which point changes in landscape material and irrigation equipment will change water use (TWDB Texas Water Development Board 2013). Evaluating savings from check-ups is complicated by yearly temperature and precipitation variations.

2. METHODS

Irrigation check-ups were conducted in College Station, a central Texas community experiencing rapid population growth. Over the last two decades, the city increased in population from 67,890 in 2000 to just over 100,000 in early 2010 (Hester 2014; Hester and Prochazka 2012). It has a reliable water supply drawn entirely from groundwater, primarily from the Simsboro Sand formation of the Carrizo-Wilcox Aquifer. Groundwater as a water source is less susceptible to drought limitations than surface water sources (for example Austin, Lower Colorado River Authority and the North Texas Municipal Water District), but this also makes imparting a conservation message difficult, because water supply is constrained by infrastructure limitations rather than disruptions in supply.

College Station's customer base is approximately 92 percent single and multi-family residential and eight percent commercial. "Commercial" customers in College Station are defined as all non-residential customers including municipal parks and open space, schools, retail properties and hospitals. On a yearly basis 50 percent of water use is attributed to residential single-family, 30 percent to residential multi-family, and 20 percent to the commercial customer class.

During the fall, winter and early spring months, daily water use in College Station averages 8 to 10 million gallons per day (MGD), but during the peak irrigation months of May through September, usage increases to 20 – 25 MGD. In contrast, daily wastewater flow, representing indoor water use, remains relatively constant throughout the year at approximately 7 MGD. This translates to a peak – to – average ratio (peaking factor) of 1.7 to 2.1, meaning peak day usage is double average daily usage (City of College Station 2014). The difference between peak daily water use and average daily wastewater treated can reasonably be attributed to outdoor water use, primarily landscape irrigation. This is consistent with a recent statewide study which found that approximately one third of annual residential single-family water use is attributed to outdoor, mostly landscape, use (Cabrera et al. 2013; Hermitte and Mace 2012).

In order to provide water for new customer growth, realize significant reductions in peak water usage, reduce stress on existing water infrastructure and delay the drilling of expensive new water wells, conservation is recommended as the first water management strategy, followed by wastewater reuse and additional groundwater development. Water conservation represents reduced operating costs, reduced pumping fees to the Brazos Valley Groundwater Conservation District (BVGCD), and delayed addition of expensive new wells. A variety of recommended Best Management Practices for water conservation is expected to contribute to 1,164 acre-feet per year of College Station's projected 2060 deficit (TWDB Texas Water Development Board 2012).

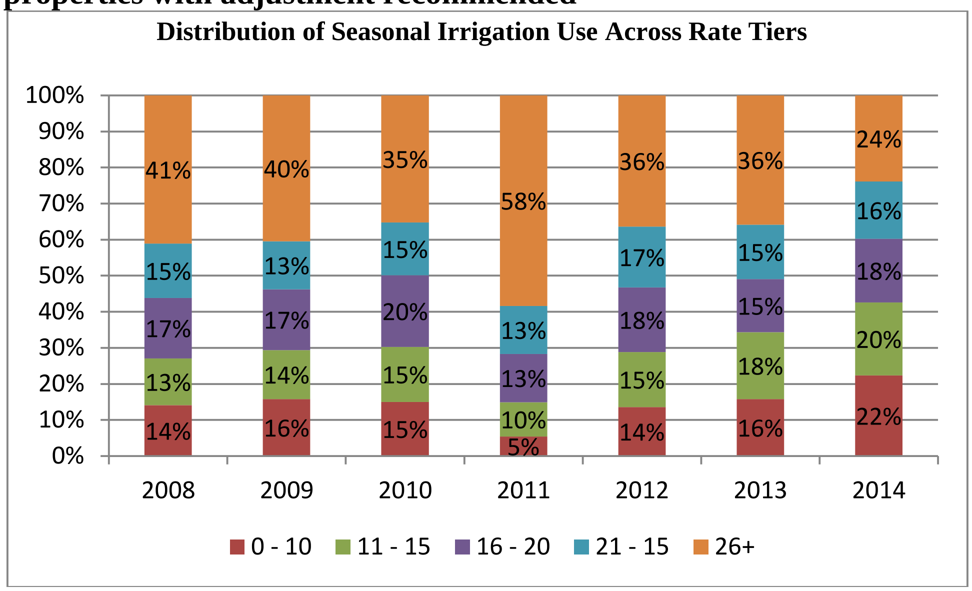
Landscape irrigation checkups are offered as a free service to all College Station water customers who have an automatic in-ground irrigation system, and thus are likely to use more water than customers without irrigation (Bremer et al. 2012; Endter-Wada et al. 2008). These irrigation check-ups followed the procedures previously described. The irrigation check-ups offered to College Station water customers are intended to point out sources of water waste to customers and give them specific recommendations for improving water use efficiency. These landscape irrigation checkups cover the "site inspection" step of an irrigation audit as described by the Texas Agrilife Extension Service but do not include distribution uniformity or soil moisture measurements as described in other literature about irrigation evaluations (Glenn et al. 2015; GreenCO and Wright Water Engineers Inc. 2008; Taylor et al. 1999; Thomas et al. 2009).

Between 2010 and 2013, a total of 374 irrigation check-ups were performed throughout College Station. These irrigation checkups were available to all College Station water customers—not just the high end water users. A subset of 173 properties, representing large volume water users, was selected for further analysis. This subset of properties also contains some of College Station's higher water users, indicated by where their usage falls in College Station's graduated water rate structure. The City of College Station maintains an inclining block water rate structure to encourage water conservation, detailed in Table 1 and Figure 1 (City of College Station 2012). In order to be most effective, irrigation evaluations should target high water users, such as those in the top tiers of citywide water use, and it appears College Station's irrigation checkup service is reaching some of these customers.

Table 1. Distribution of seasonal (April – September) water use across rate tiers, for all properties with adjustment recommended

		# Properties per Tier, Irrigation Season April - Sept						
Rate Tier	$ per Kgal	2008	2009	2010	2011	2012	2013	2014
0 – 10 kgal	$2.26	24	27	26	9	24	27	39
11 - 15	$2.94	23	24	26	17	26	32	35
16 - 20	$3.61	29	29	34	23	31	26	31
21 - 25	$4.28	26	23	25	23	29	26	28
26 kgal and up	$4.96	71	70	61	101	63	62	41
		173	173	173	173	173	173	173

Figure 1. Distribution of seasonal irrigation use across water rate tiers for properties with adjustment recommended



Records for all properties receiving an irrigation checkup and water budget during the period of 2010 – 2013 were reviewed and divided into “Adjustment Recommended” and “No Adjustment” by year. These results are summarized in Table 2. “Adjustment recommended” includes any type of adjustment – changing watering days, reducing run times, fixing mechanical issues, or some combination. In some cases properties had multiple types of adjustments recommended while other properties had a single adjustment recommended. Controllers programmed to run more than two days per week, or having run times of longer than 20 minutes in one cycle were included as “adjustment recommended.” Due to heavy clay soils in most of College Station, single run times longer than 20 minutes are likely to result in runoff because the soil can’t absorb all of the water. Enough irrigation water can be applied in one to two irrigation days per week. Mechanical issues such as leaks, inefficiencies in design, misdirected or broken sprinkler heads, problems with the controller or valves, and other issues related to lack of routine maintenance were also noted on irrigation checkup reports. Customers without any adjustment recommended are not included in this study.

Table 2. Summary of irrigation check-up results on properties with adjustment recommended

Year of Checkup	2010	2011	2012	2013	TOTALS
Adjustment recommended	50	44	36	43	173

In each year, seasonal irrigation use for properties with an adjustment recommended was compared on a year-to-year basis as well as to average seasonal irrigation use for the years prior to and after the checkup. Estimated irrigation use was obtained by subtracting average winter consumption (November – January) for each account from monthly billed water usage for the irrigation season of April – September. For the years following the checkup, properties reducing their water use were compared with properties increasing their water use to determine any trends, and also calculate overall savings.

Next, each property's estimated seasonal irrigation use was compared with the seasonal irrigation budget on a year-to-year basis. In some cases many properties remained over-budget from one year to the next, but still saved water and moved closer to their suggested irrigation budget in following years. Properties were sorted according to amount of water over budget, and the amount over budget in the year of the irrigation checkup was totaled. Irrigation use for this subset of properties was tracked for subsequent years, to determine if any of these properties remained over budget, and calculate overall savings. These over-budget households represent chronic overwatering practices. Thus, in many cases, a small number of households reducing water use amounted to substantial water savings by bringing their water use within the recommended irrigation budget.

3. RESULTS AND DISCUSSION

3.1 Impact of Irrigation Checkups on Change in Seasonal Irrigation Use

The first objective of this study was to determine change in seasonal irrigation use for properties with an adjustment recommended. An adjustment may include reducing watering days, run times, fixing leaks, or a combination of recommendations.

In the first year of the study, 2010, 50 properties had an adjustment recommended. The first year following these checkups was the historic drought year of 2011. Forty-three properties increased use and just 7 properties decreased use in 2011, resulting in a net increase of 1.827 million gallons. However, in each of the next three years, there was a consistent pattern of reduction, with savings of 1.154 million gallons in 2014, as shown in Table 3.

Table 3. Change in seasonal irrigation use from irrigation checkups in 2010

	2010	2011	2012	2013	2014
Total Seasonal irrigation use	4,989	6,817	4,689	4,789	3,835
Change from 2010		1,827	(299)	(200)	(1,154)
Decrease (N)		7	30	24	39
Increase (N)		43	20	26	11

*Note: figures in thousands of gallons

In 2011, 44 properties receiving irrigation checkups had one or more adjustments recommended. Because 2011 was a drought year, it can be expected that these properties would show savings comparing 2012 to 2011. However, comparing seasonal irrigation use for 2009 – 2010 with 2012 – 2013, 22 of the 44 properties reduced their irrigation usage, for a total reduction of 612,369 gallons (see Table 4). This is an 11% decrease and is consistent with savings in published literature (GreenCO and Wright Water Engineers Inc. 2008; Gregg et al. 2007; Rice 2009; TWDB Texas Water Development Board 2013).

Table 4. Change in seasonal irrigation use from irrigation checkups in 2011

	2011	2012	2013	2014
Total Seasonal Irrigation use	8,187	5,309	4,894	4,352
Change from 2011		(2,878)	(3,294)	(3,835)
Decrease (N)		38	40	40
Increase (N)		6	4	4

*Note: figures in thousands of gallons

In 2012, 36 properties receiving irrigation checkups were in need of adjustment. In 2013, 22 properties reduced usage for a net savings of 164,430 gallons. While this is a modest reduction of just 5%, it is still consistent with savings demonstrated in the literature (GDS & Associates 2002; Nelson 1992; Rice 2009). In 2014, 30 properties reduced usage compared to 2012, resulting in a net savings of 844,000 gallons, or 24% compared to 2012.

Nearly all (34) of the 43 properties with an adjustment recommended in 2013 reduced their usage in 2014, resulting in a savings of 760,560 gallons, an average reduction of

17,690 gallons per household. Mean seasonal irrigation use per household for 2008 – 2012 was 97,412 gallons, compared to 67,028 gallons in 2014.

3.2 Analysis of Savings based on Water Budgets

Landscape irrigation audits show how efficiently a landscape irrigation system is operating, but they don't necessarily provide information on the amount of water the landscape needs. A standard recommendation of landscape water need is 1 to 1.5 inches of water per week for turf grass, but irrigation users don't often know how much water this is (Bremer et al. 2012).

A landscape water budget considers reference evapotranspiration rates for an area, type of plant in landscape (for example, woody ornamentals, vegetables, or warm-season turf), landscape size, type of irrigation system, and rainfall amounts (Al-Kofahi et al. 2012; US EPA U.S. Environmental Protection Agency 2014; White et al. 2004). The EPA WaterSense Water Budget tool refines the water budget from a simple amount of water needed to a determination of a landscape water allowance in which a certain amount of water can be applied while still remaining water efficient (US EPA U.S. Environmental Protection Agency 2014).

Outdoor landscape water use can be determined by subtracting estimated indoor water use from the total water use. Once outdoor landscape water use is determined, this can be compared with landscape water need to determine if a customer is applying more or less water than their landscape needs.

Changes in estimated irrigation consumption before and after an irrigation checkup can determine the impact the irrigation checkup had on water consumption, and how long this impact lasted. Evaluating water use for customers who were over-budget prior to receiving an irrigation checkup may explain the impact of irrigation checkups and water budgets on landscape water use.

The water budget, sometimes called the Landscape Water Allowance or Irrigation Requirement, is a function of reference evapotranspiration (ET_0), a plant adjustment factor, and an estimate of irrigation area (St. Hilaire et al. 2008; US EPA U.S. Environmental Protection Agency 2014; White et al. 2004). For this study, water budgets were developed based on an assumption that the landscape was dominated by St. Augustine turf, a warm-season turf grass common in College Station residential landscapes, and irrigated area was assumed to be lot size in square feet minus an estimate of heated area and hardscape surfaces, as determined by Brazos Central Appraisal District records and aerial photography (Lewis 2014).

$$\text{Water Budget} = [K_c \times ET_0 \times P] \times \text{Irrigated Area } (ft^2) \times 0.6 \text{ gal} / ft^2 \qquad (1)$$

Where

K_c: a crop coefficient for St. Augustine grass (0.65)

ET_0: represents average monthly reference evapotranspiration (inches)

P: precipitation measured in inches by National Weather Service at Easterwood Airport

Wintertime average monthly water use for each household was subtracted from monthly water use records, resulting in a water budget that reflected only estimated outdoor water use needs, and allowed for relevant comparisons regardless of household or lot size. Adding detailed water budgets to the study protocol resulted in a database of actual vs. budgeted residential outdoor water use over a four-year period, one year of which was a drought of historic proportions.

The approach of identifying above-average water use compared to that of a specific group (i.e., neighborhood) combined with actions to reduce water use uses a concept called social norms marketing. Social norms marketing provides people with information on how their behavior (in this case, water use) compares to what is considered outside or within what is considered “normal” or “typical” as well as specific information on how to change their behavior to approach the norm (Schultz et al. 2008). The concept is that people will be motivated to change behavior if they are shown information that their behavior is outside of the norm (estimated water budget and neighborhood average) and given specific information on how to change their behavior to approach the norm (landscape irrigation evaluations).

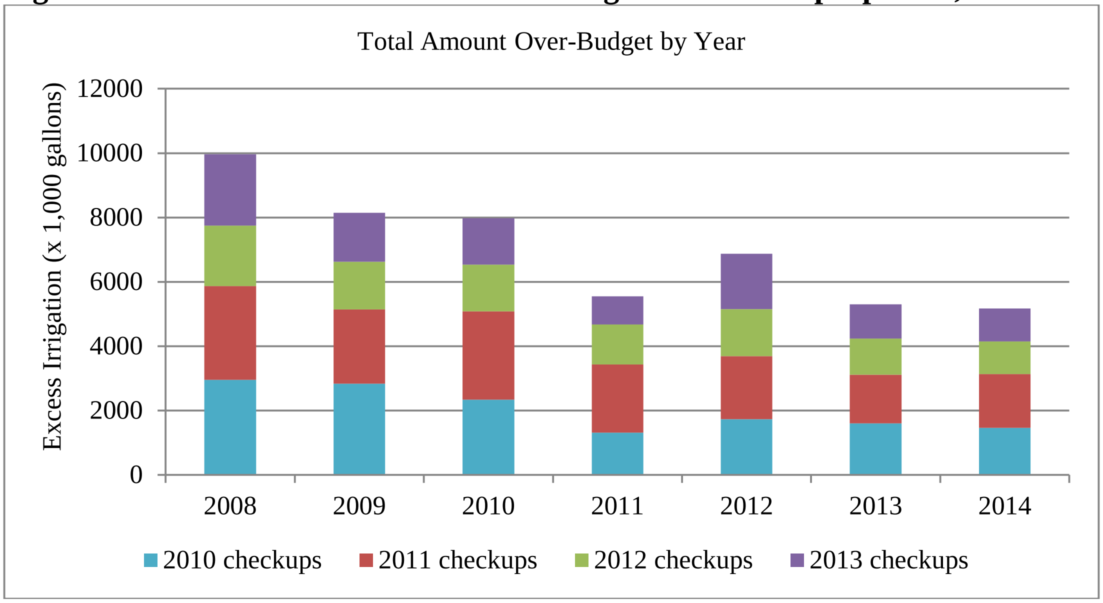
Recent research indicates strong social norms motivation for Texans to conserve water, with respondents rating saving money on water bills, saving water for future generations, and conserving water in extreme drought as important motivator for using less water (Boellstorff et al. 2010; Stoutenborough and Vedlitz 2013).

3.3 Impact of Irrigation Checkups on Excess Irrigation (Over-Budget)

Next, the impact of receiving an irrigation budget combined with an irrigation checkup will be summarized by reviewing changes in the amount by which customers exceeded their irrigation budget.

In each year, water budget data for properties with an adjustment recommended was also studied. Water budgets were created using a landscape coefficient of 0.65, meaning they were designed to replace 65% of water lost to evapotranspiration, so any water used over the recommended budget represents possible excess irrigation, and thus significant potential water savings. Water budgets were compared with irrigation use for the two years prior to the checkup to establish a baseline, and this baseline was compared against irrigation use and irrigation budget for the intervention year as well as the two years following intervention, to determine if water use began to approach the recommended budget. Conformance to the water budget was also studied for the subset of properties that were over budget at the time of the checkup. Reduction in total amount over budget by year is summarized in Figure 2.

Figure 2. Reduction in amount of excess irrigation from all properties, 2008 – 2014



For the first year of the study, 43 out of the 50 properties with an adjustment recommended – 86% - were also over-budget. These 43 properties had excess irrigation in 2010 of 2,335,000 gallons. In the baseline period of 2008-2009, 46 properties overwatered by 2,855,000 gallons, but in 2011-2012 overwatering was reduced to 1,399,000 gallons, a reduction of 51%. This is likely a result of irrigation needs, and therefore irrigation budget, being higher in 2011 due to the drought. The amount of properties over budget continued to decline following the intervention.

For the drought year of 2011, 26 of the 44 properties with an adjustment recommended – 59% - were also over-budget. Excess irrigation for this group amounted to 2.121 million gallons in 2011. In the baseline period of 2009-2010 excess irrigation was even higher, with 38 out of 44 properties (85% of the group) overwatering by 2,526,000 gallons.

Nearly all (22 out of 26) – were over-budget by 25,000 gallons or more, and 18 properties were over-budget by 50,000 gallons or more for the season. Median amount over-budget was 66,203 gallons. In the response period following the checkup (2012-2013), the number of over-budget properties was reduced to 34, and total excess irrigation was reduced by 0.841 million gallons, a savings of 34%.

In 2012, 29 of the 36 properties with an adjustment recommended also exceeded their irrigation budget. Excess irrigation from these properties amounted to 1,458,451 gallons. Median amount over-budget was 45,000 gallons. In 2013, 24 of the 29 properties remained over-budget, but 18 of these properties were over-budget by less than 50,000 gallons. Excess irrigation from these 24 properties in 2013 amounted to 1,103,038 gallons, a savings of over 355,000 gallons. Although 25 properties were over-budget in 2014, the total amount over-budget was just over 1 million gallons, a savings of 455,800 gallons from 2012.

Of the 43 properties with an adjustment recommended in 2013, 33 of these were over-budget at the time of the checkup. This is consistent with usage prior to the checkup, when at least 34 out of the 43 properties were over-budget (except for the drought year of 2011). Excess irrigation from these properties amounted to 1,176,577 gallons in 2013. In the year following the checkup (2014), 23 of the 33 over-budget properties remained over-budget, and excess irrigation amounted to 875,729 gallons from these 23 properties. This is a savings of 185,600 gallons. This means nine properties changing their irrigation practices saved approximately 20,000 gallons each.

3.4 Irrigation Efficiency Index

Another way to analyze the impact of irrigation checkups on over irrigation is to compare seasonal irrigation use with a recommended irrigation budget, as an Irrigation Efficiency Index. A similar approach was used by Glenn et. al. (2015) in reviewing impact of water conservation interventions in Logan, Utah. Water budgets in this study used a Kc of 0.65 rather than 1 (replacing 65% of ET_0 rather than 100%), so a property with an IEI value greater than 2 can be considered to be inefficient. The IEI value is obtained by dividing the total amount of seasonal irrigation use by the recommended seasonal irrigation budget.

$$\text{IEI: Seasonal Irrigation Use / Seasonal Irrigation Budget} \qquad (2)$$

Glenn et al averaged irrigation index values for the 2 years prior to and following the irrigation check to determine impact. Following this method, baseline and response IEI values can be obtained for properties with irrigation checkups done in 2010 - 2012 that were over budget at the time of their checkup (see Table 5, Table 6, and Table 7). Baseline values for irrigation checkups conducted in 2012 would have the drought year of 2011 included, and thus could be skewed low.

Table 5. Irrigation efficiency indices for over budget properties with irrigation checkups in 2010

	2008	2009	2010	2011	2012	2013	2014	Baseline 2010	Response 2010
N > 2	26	19	23	3	12	9	8	26	5
N < 2	17	24	20	40	31	34	35	17	38

Table 6. Irrigation efficiency indices for over budget properties with irrigation checkups in 2011

	2008	2009	2010	2011	2012	2013	2014	Baseline (Avg 09-10)	Response (Avg 12-13)
N > 2	18	13	19	5	16	5	7	19	10
N < 2	8	13	7	21	10	21	19	7	16

Table 7. Irrigation efficiency indices for over budget properties with irrigation checkups in 2012

	2008	2009	2010	2011	**2012**	2013	2014	Baseline (Avg 10-11)	Response (Avg 13-14)
N > 2	16	12	15	2	**10**	4	8	8	7
N < 2	13	17	14	27	**19**	25	21	21	22

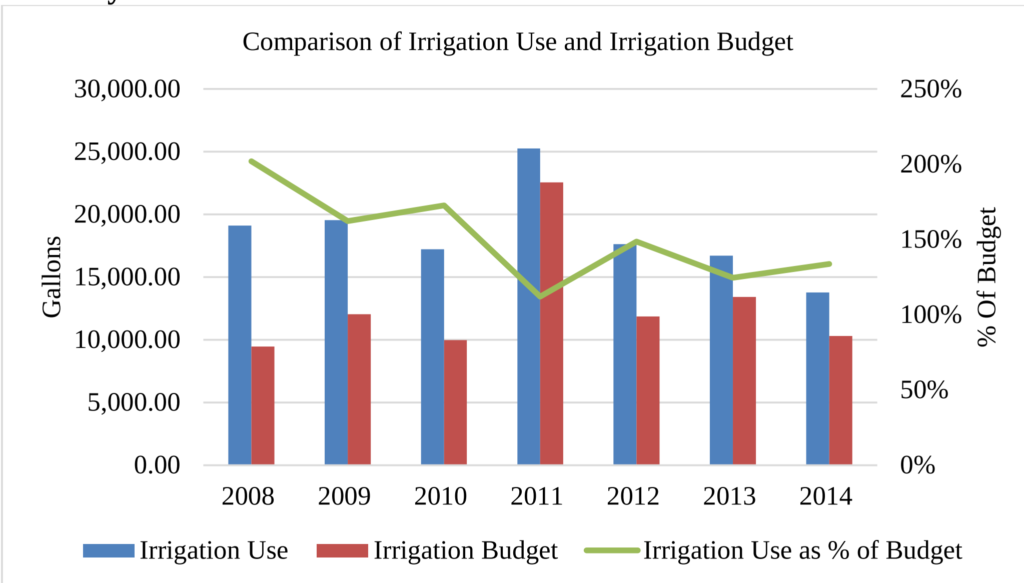
The small number of properties with an IEI value of more than 2 in 2011 could be an indication that although irrigation use was higher in 2011 due to the drought, irrigation need was also higher, and customers as a whole under-irrigated that year.

There were 26 over-budget properties with irrigation checkups conducted in 2011, and 19 of these had a baseline IEI value higher than 2. Following the checkup, the number of properties over-budget was reduced to 10. This means nearly all of the over-budget properties were irrigating twice as much as needed, and following the checkup less than half of the over-budget properties were over-irrigating.

Calculating a baseline IEI value for properties with irrigation checkups conducted in 2012 is more difficult because the “baseline” includes the drought year of 2011. When the baseline is calculated based on averaging 2009 and 2010 irrigation use, there were 12 out of 29 over-budget properties with an IEI of 2 or more prior to the checkup. Following the checkup, this number was reduced to 7. Similar to 2011, nearly half of the over-budget properties were applying twice as much irrigation water as needed prior to their checkup, and following the checkup nearly all properties were irrigating efficiently.

Comparing seasonal irrigation use and irrigation budget for all properties from 2008 to 2014 (see Figure 3), it becomes clear that in 2008 the properties included in this study were using twice as much water as their landscapes needed. In 2008, irrigation use for all 173 properties (19.119 million gallons) was 2.02 times the irrigation need (9,467,000 gallons), and by 2014 irrigation use (13,781,000 gallons) was 1.34 times the irrigation need (10,298,000 gallons). In 2011, irrigation use most closely approached irrigation need, which is likely a reflection of higher irrigation budget needs and customers irrigating less than landscapes needed. However, IEI values following 2011 were still lower than prior to 2011, indicating that some customers may have learned during the drought of 2011 that their landscapes could survive on less water than previously believed.

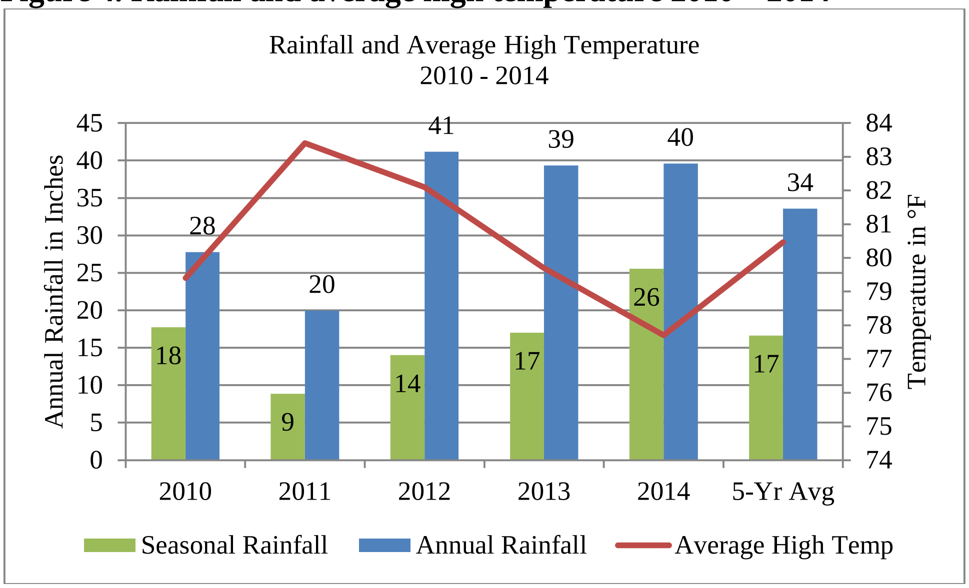
Figure 3. Comparison of irrigation use and irrigation budget for all properties in the study



3.5 Influence of Rainfall and Drought on Water Use

A customer's water budget was calculated based on historical monthly precipitation, landscape size, and historical ET amounts, according to Equation 1. However, if most of the rain in a particular month fell towards the end of a month, and the customer irrigated before that, the customer may appear to be over budget in a single month. As shown in Figure 4, below, the variability in seasonal rainfall from year to year may have had an impact on irrigation use. Rainfall amounts for 2012 - 2014 were similar (41 inches in 2012, 39 inches in 2013, and 40 inches in 2014), but annual distribution of rain was highly variable (see Figure 4). In 2012 and 2013, most of the annual rainfall came outside of the irrigation season (January – March in 2012; January and October in 2013), whereas in 2014 over half of the annual rainfall (26 inches) fell during the irrigation months of May, July, and September. The large increase in savings for 2014 compared to all previous years, as well as reduction in number of properties over-budget, could be an indication that these properties understood the concept of an irrigation budget and changed their irrigation practices in response to the increased rainfall.

Figure 4. Rainfall and average high temperature 2010 – 2014



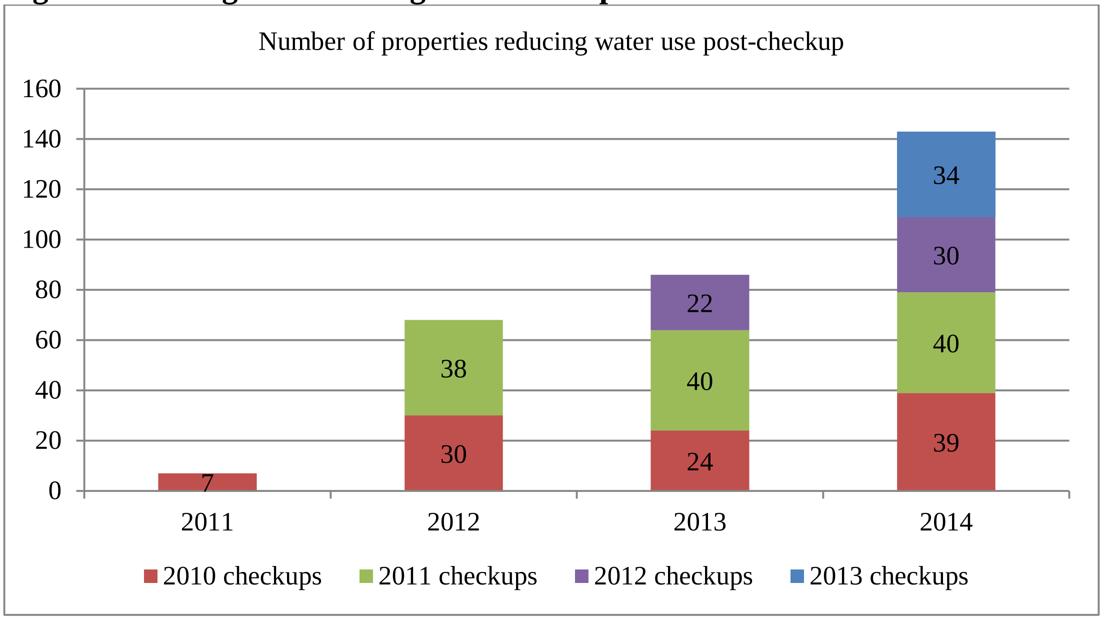
4. SUMMARY AND CONCLUSIONS

The research presented in this paper was intended to demonstrate causes of overwatering in the landscape, document any reductions in seasonal water use after receiving a landscape irrigation checkup, and determine how long any conservation impacts lasted.

Wasted water in the landscape can be tied to improper irrigation system maintenance, poor or outdated system design, and lack of operational knowledge of the irrigation system (Endter-Wada et al. 2008; Gregg et al. 2007). This is why the landscape irrigation checkups conducted by the City of College Station focused on educating customers about proper run times including the “cycle and soak” method of irrigation scheduling, pointing out how to adjust sprinkler heads to not water impermeable surfaces, and sharing information about modern sprinkler system components such as rain sensors and efficient sprinkler heads, to build efficiency into the system as repairs are made.

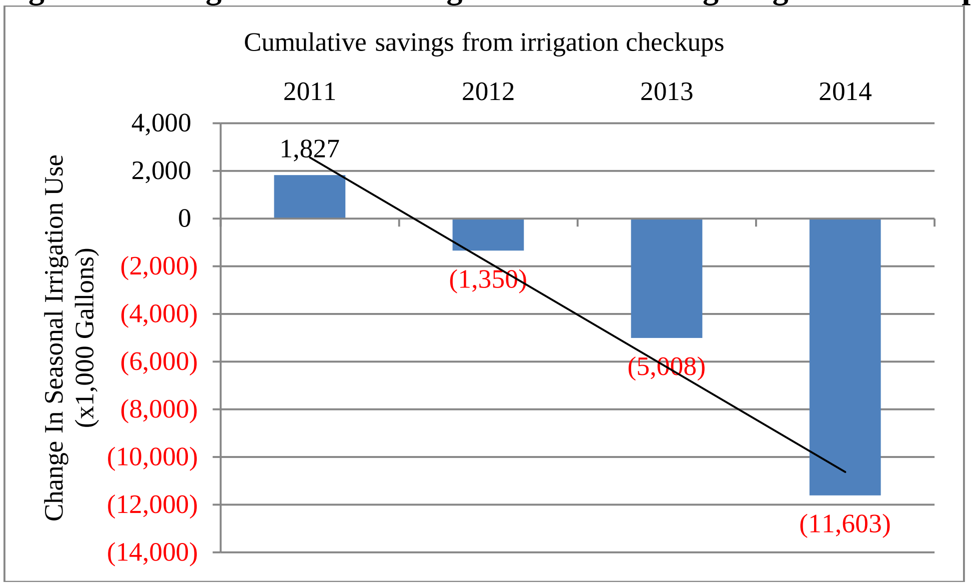
Published literature (GDS & Associates 2002; Gregg et al. 2007; Rice 2009) indicates that savings from an irrigation checkup can be expected to last up to three years post-intervention, and that these interventions can produce savings of between 5% and 30%. As shown in Figure 5, water savings from properties receiving irrigation checkups persisted for at least three years following intervention.

Figure 5. Lasting effect of irrigation checkup



Water savings from all 173 properties with an adjustment recommended between 2010 and 2013 amounts to 11.7 million gallons over the four year period of 2011 – 2014 (see Figure 6). This shows that irrigation checkups, and continuing attention to water conservation in the landscape, can result in significant improvements in water conservation for water utilities that have a high proportion of customer water use going to landscape irrigation.

Figure 6. Change in seasonal irrigation use following irrigation checkup



Water use can be influenced by household size, weather conditions, or change in property ownership, so a simple comparison of change in seasonal water use does not provide enough level of detail. Water budgets, in general, address water need based on landscape size and plant type. Water budgets in this study assumed St. Augustine turf in full sun, with a landscape coefficient of 0.65, and did not account for differences in plant species, irrigation system efficiency, and sun exposure or soil type. This limitation, also noted in other studies, (Pannkuk and Wolfskill 2015; White et al. 2004) likely resulted in a relatively conservative water budget, so that customers who exceeded their water budget were most likely truly overwatering. Thus, a reduction in amount over budget for a property that has consistently exceeded that water budget is an indication of improved water use efficiency.

Pannkuk and Wolfskill (2015) noted widespread overwatering in their study conducted on residential water use in a similar East Texas community. They suggested that providing homeowners with a water budget would increase customer awareness for water conservation. White et. al. came to a similar conclusion with their 2004 study, that savings could be increased by showing customers a water budget (White et al. 2004). It is encouraging to note that this was done for fifteen neighborhoods in College Station, and demonstrable savings were achieved in properties over their irrigation budget. It is not known, however, if these reductions were due solely to receiving the irrigation budget, if they were enhanced by having a landscape irrigation checkup, if they were in response to water rates, or some combination of factors.

The most striking results, and greatest water savings, came from the properties that were extremely over budget. In reviewing water use from 2008 to 2014 for the properties included in this study, total amount over-budget went from 9.9 million gallons in 2008 to just over 5 million gallons in 2014, as shown in Table 8 below.

Table 8. Reduction in amount of excess irrigation from properties with adjustment recommended, 2008 – 2014

Excess Irrigation By Year	2008	2009	2010	2011	2012	2013	2014
2010 checkups	2,949	2,837	2,336	1,309	1,730	1,601	1,456
2011 checkups	2,923	2,307	2,746	2,121	1,963	1,514	1,672
2012 checkups	1,881	1,476	1,452	1,241	1,458	1,123	1,020
2013 checkups	2,216	1,527	1,447	878	1,717	1,061	1,021
Total excess irrigation	9,968	8,146	7,981	5,548	6,869	5,299	5,171

Results of the analysis demonstrated that there is value in identifying high-volume residential customers and providing instruction to improve efficiency in watering practices. The higher-volume water customers in this study were also located in neighborhoods with higher than average property values, deed restrictions specific to landscape maintenance such as requiring irrigated turf covering all or most of the front yard, and active homeowner associations enforcing the deed restrictions. Inroads to changing water use can be made by developing partnerships with homeowner associations, providing hands-on instruction to improve watering practices, and educating customers as well as property managers about proper landscape maintenance.

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APPENDIX

A-1. Sample customer letter

College Station Utilities
Reliable, Affordable, Community Owned

Water Services Department
P.O. Box 9960
College Station, TX 77842
http://www.cstx.gov/water

CITY OF COLLEGE STATION

June 13, 2012

College Station Water Customer

Dear Customer:

Having an adequate supply of water in the future depends on the conservation actions we take today. Over the past several years we have analyzed water use patterns and estimated water needs to evaluate the effectiveness of water conservation programs. Two of the most customer-requested items have been to compare water use on a neighborhood rather than citywide basis, and to provide information on how much and how often to water, based on actual landscape needs.

You asked, and we listened! Enclosed you will find charts comparing your actual water usage over the past three years with an estimated lawn / plant irrigation water budget, as well as comparisons with neighborhood average water use.

Some notes about the water budgets:

- The budgets are based on evapotranspiration rates which includes water loss from plant growth plus evaporation of water from plant leaves. To put that in perspective, turf in full sun in College Station requires about 1 inch of water per week, (rain or supplemental irrigation). One inch of water is 0.6 gallons per square foot.
- The red line on the charts is the estimated water budget for your yard and the blue bar is your estimated outdoor water use. If you have a blue bar omitted it's because city data was missing for that month.
- For months where landscape water needs were met by rainfall alone, the water budget is zero. For example in May and June of 2010, rainfall supplied all of turf water needs. In contrast, last year July and August set records for heat and drought and the water budget was very high.
- **UNDER-BUDGET OR BELOW-AVERAGE WATER USE:** If your charts show you are under-budget or below average for your neighborhood – *keep up the good work!*
- **OVER-BUDGET OR ABOVE-AVERAGE WATER USE:** You may be able to realize substantial savings on your water bill by using conservation prctices, such as covering a swimming pool, fixing irrigation leaks, or adjusting your irrigation controller.

If you fall into the "over-budget" or "above-average" category, we would encourage you to consider adjusting your lawn irrigation system based on rainfall during a week. As further help we invite you schedule ***a FREE landscape irrigation check-up. A consultant to College Station Water Services will visit with you at your home, observe your irrigation system, and answer your questions about water use and conservation. Please call Jennifer Nations at 979-764-6223, or email jnations@cstx.gov, as soon as possible to schedule your FREE landscape irrigation check-up.***

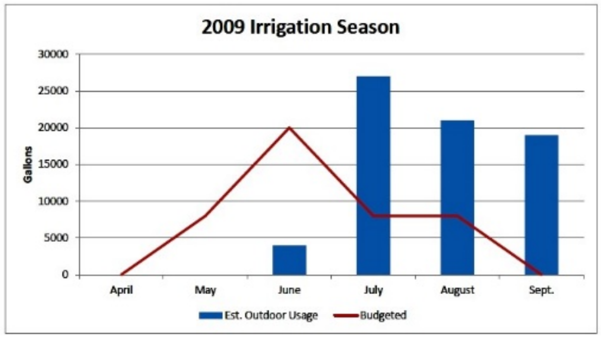
The data collected from this analysis will be used to evaluate the best methods for conserving water in College Station. The results of this analysis may be presented at meetings or in publications; however, your identity will not be disclosed in those presentations.

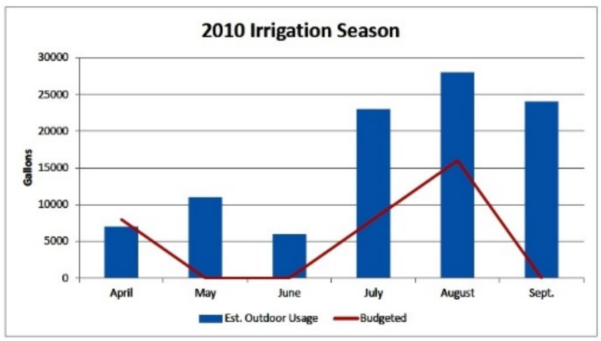
Your voluntary participation is an important part of College Station's water conservation effort. If you need further information on any of our conservation programs, please visit www.cstx.gov/water or contact Jennifer Nations.

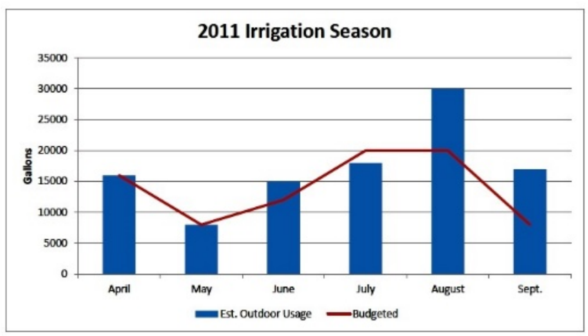
With best regards,

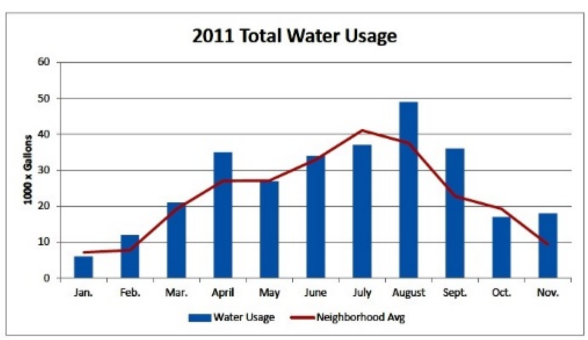
David M. Coleman, P.E.
Director of Water Services

A-2. Sample irrigation budget graph









A-3. Sample Irrigation Checkup Report with findings

CITY OF COLLEGE STATION

Irrigation System Check-Up Report

WATER IQ
Know your water.

http://www.wateriq.org

WATER SERVICES

http://www.cstx.gov/water

Rain Sensor Y / N

Backflow Preventer AVB DCV PVB RPZ N/A

Performed By	Customer Name		Date	Time
Controller Model	Address	LOCID:	Email Address	

Station #	Sprinkler Type	Plant Type	Current Run Time	Current Days	Suggested Run Time	Suggested Days	Area being Irrigated
1	rotors	St. Aug.	40(A) x 2 cyc	M,T,F(A)	30	Tu, Sa	Front circle lawn, sun
2	rotors	St. Aug.	30(A) x 2 cyc	M,T,F(A)	25	Tu, Sa	Font N. side lawn, sun
3	sprays	St. Aug/shrub	25(A) x 2 cyc	M,T,F(A)	15	Tu, Sa	Front garage lawn & front beds, sun
4	sprays	St. Aug.	20(A) x 2 cyc	M,T,F(A)	15	Tu, Sa	Side lawn & back beds, part sun
5	rotors	St. Aug.	40(A) x 2 cyc	M,T,F(A)	30	Tu, Sa	Back lawn near house, part sun
6	rotors	St. Aug.	*38(A), 40(B)	M,T,F(A), M(B)	30	Tu, Sa	Back middle lawn, sun
7	rotors	St. Aug.	*30(A), 40(B)	M,T,F(A), M(B)	30	Tu, Sa	Back middle lawn, part sun
8	rotors	St. Aug.	*35(A), 40(B)	M,T,F(A), M(B)	30	Tu, Sa	Back lawn near pond, sun
	All stations were set to run on the (A) program for (2) cycles (12:00 AM & 3:15 AM) for times listed.						
	***Stations 6-8 were also set to run on the (B) program for (2) cycles (12:00 AM & 12:15 AM).**						

Station #	Problems Observed
1	None
2	(1) leak underneath sprinkler head located at corner of street and driveway.
3	(1) sprinkler was disconnected from underground pipe. (This was corrected on-site.)
4	None
5	None
6	(1) rotor on N. end near fence not turning; (1) rotor on S. end near fence not turning.
7	(2) rotors on S. end need to be raised.
8	None
9	
10	

Comments:

At the time of the inspection the controller was set to run on the (A) and (B) programs for the run times listed above. All stations were running the listed times for (2) cycles on Mondays, Tuesdays, and Fridays. In addition, stations 6, 7, and 8 were running on the (B) program for (2) cycles on Mondays. The suggested irrigation days and run times are based upon typical plant water requirements for this type of year and are adjusted for differences in station application rates and sun exposure. ***At your request, I reprogrammed the controller with the recommended schedule before leaving the site.*** No major problems were observed during the inspection; however, there were several minor problems that should be addressed. These are listed above. Finally, consider installing a rain shut off device to prohibit irrigation during and directly following significant rainfall events. This connects to your controller and is available in both wired and wireless models.